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ANALYSIS OF CONSTRUCTION AND INITIAL PERFORMANCE OF THE CHINA GLENN ROAD, WARREN DISTRICT, PAYETTE NATIONAL FOREST

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Abstract

The Idaho Batholith has a history of erosion and sedimentation problems associated with logging and road construction. These problems are particularly acute in areas sensitive to sedimentation. The South Fork of the Salmon River is such an area because it is a spawning and rearing stream for salmon and steelhead trout. Because of a history of watershed damage in the South Fork drainage, the China Glenn Road was the first to be built there for many years. This particular road project sparked unusual interest because it was to be constructed with a minimum amount of environmental impact. A Forest Service engineering research team analyzed the construction and initial performance of the China Glenn Road, Warren District, Payette National Forest, and reported its findings.

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INTRODUCTION

The China Glenn Road was designed to serve a salvage timber sale in the K Creek, China Creek, and Big Flat Creek watersheds on the Warren Ranger District, Payette National Forest. The sale was proposed as the result of an entomological detection flight, June 6, 1969, by the Boise Zone entomology section, of subsequent mapping flights, and field reconnaissance studies. Observations indicated that a large, rapidly expanding population of Douglas-fir beetle, *Dendroctonus pseudotsugae* (Hopk.), had already damaged many trees and was threatening many others.

To minimize watershed damage in the Idaho Batholith, Forest Service managers decided that the China Glenn Road was to be designed and located for minimum impact. The road standard used, SL-12 outsloped, called for turnouts and a 90-ft. minimum radius of curvature. The design provided for surface drainage by means of intercepting dips and riprapped culverts. Elevation of the road ranges between 5,800 and 6,300 ft., which is generally believed to be above the high-hazard elevation zone for rain-on-snow climatic events. For the most part, the route avoids very steep (over 65 percent) portions of the terrain. Specifications limited fill slopes to a maximum of 1½:1 (67 percent) and cut slopes generally to 1:1 (100 percent). Although no end-point compaction specifications were included in the road contract, the designers considered compaction needs. After testing soil samples, they decided that normal traffic and excavation equipment would provide sufficient compaction.

Personnel of the Payette Forest and Warren District exercised professional judgment in the location, design, staking, and inspection of construction of the China Glenn Road. This report presents the findings and conclusions of a team from the Forest Engineering Research project, Intermountain Forest and Range Experiment Station, on the initial phase of this road project.

INVESTIGATION

The decision to observe construction practices and evaluate the adequacy of a road designed to minimize watershed impact was made little more than a month before construction began. Although no detailed preconstruction soil investigations were possible, two trips were made to the area to test the usefulness of seismic equipment for subsurface investigations. In addition, the route was traversed by foot and large marking crosses were spaced approximately one-half mile apart for identification on aerial photographs. During the latter part of July 1970, intermediate and low altitude flights were made over the area and aerial photographs were taken.

Construction began the last week of July, continued through August and into September. Timber harvesting began shortly after construction got underway and was continued almost to the end of September.

Members of the research team remained at the site through August and part of September. During that time, operations were described and photographs taken. The sole purpose of this part of the investigation was to observe construction methods and equipment for evaluation of their effectiveness.

During the 4-day Labor Day weekend, a heavy rainstorm occurred in the area; estimates indicated that perhaps 2 to 3 inches of precipitation fell September 4-7. Unfortunately, no one was there to record the timing and mode of soil movement, but the results of the erosion caused by the storm were extensively photographed and described September 8, 9, and 10. In addition, estimates were made of the quantities of soil eroded and the extent of soil transport.

Preconstruction

Examinations of cuts and fills along existing roads and analyses of samples obtained by Payette Forest personnel indicated that the soils and disintegrated rock in large parts of this area were similar to those throughout the Idaho Batholith. Thus, it is reasonable to assume that the strength and permeability characteristics of these materials are also similar to those determined from intensive investigations in the Krassel District, Payette National Forest. Results of moisture-density tests were also similar to those previously obtained in the Zena Creek area. As a consequence, the major interests in our preconstruction investigation were the slopes, soil depths, and water conditions along the proposed route.

Side slopes in the vicinity of the route were highly variable and generally more gentle than those at lower elevations. The route of the proposed road center line was quite undulatory, especially along north- and east-facing slopes; gentle swales and ridges were alternately spaced at distances of about 100 ft. Vegetation was moderately dense on the north- and east-facing slopes. Even on many south-facing slopes, dense underbrush grows beneath a mixed overstory of pine and fir. This combination of gentler slopes (less than 50 percent) and dense vegetation was evidence of deep, moist soil conditions.

Attempts to confirm the appearance of deep soils by means of seismic equipment were unsuccessful. Several traverses were run, but complex subsurface conditions produced results that were difficult to interpret. Results indicated complex jointing and mixing of gruss with denser rock and no pattern was readily identifiable. Only where surface topography was reasonably uniform and free of rock outcroppings were seismic time versus distance relationships reasonably meaningful. In such cases, the evidence for deep, loose soils and gruss was strong.

Construction

Boise Cascade Corp., the timber purchaser, contracted road construction and logging to J. I. Morgan and Co. The contractor (Morgan) has been involved in the past in many timber sales on the Payette National Forest, but controls were not as rigid. This sale, the first in several years in the South Fork of the Salmon River drainage, demanded special attention because of the area's history of problems. Experience has shown the area to be highly susceptible to erosion, which has led to sedimentation and damage to the fishery habitat. For these reasons, a full-time inspector from the Payette Forest engineering staff was assigned to the road construction. Also, the road was slopestaked to control alinement and grade. Both measures were taken to afford greater control over construction of the road than had been exercised on previous timber sales. In addition, the contractor cooperated fully in attempting to achieve the desired results.

In the following review of the construction, it may appear that this report is quite critical of the project. In all fairness, the road construction was accomplished in a much better manner than has been the case on most other timber operator-built roads. The purpose of the criticism is to point out areas where improvements may be possible. Some of the criticism and suggestions may seem unrealistic and impractical, but they are presented in order to provoke thought concerning the problems.

OBSERVATIONS AND RECOMMENDATIONS

Clearing

The clearing operation presents some of the most troublesome and challenging problems of roadbuilding on steep terrain. The crawler-type tractors used in the clearing operation are difficult to operate on steep side slopes. A pioneer road was built over a large portion of the China Glenn route to provide a level area from which tractors could maneuver (fig. 1). The need for a pioneer road results from the danger of such machines tipping over while contouring slopes approximately 50 percent or greater. On extremely steep slopes, the tractors often work into places near the lower clearing from which they cannot climb back up the slope. In this situation, another tractor located on the level area can winch the clearing tractor up the slope.

The authors acknowledge that a pioneer road is required to facilitate clearing with equipment presently available. However, excavation before clearing is completed defeats the main purpose of clearing because slash and organic debris are mixed with excavated material (figs. 1 and 2). This mixed material should not be pushed to the edge of the clearing with other slash because it can contribute to the sedimentation problem. On the other hand, it should not be used as fill material because of its organic content. Apparently, the answer to this dilemma lies in the development of specialized clearing equipment that can operate on steep slopes.

Until such equipment is available, decisions will have to be made as to what actions will have the least detrimental effects. In some cases, a project may have to be deferred until new equipment is available or economic values change and we can afford to work without causing unacceptable environmental impact (e.g., clearing by hand).

For the present, tractors that have the lowest center of gravity available and are equipped with a brush blade would be the most logical choice for clearing. Experience on this job showed that a D-7 Cat complete with a cable-operated sidecast blade was easier to operate on steep slopes than the newer hydraulic-equipped D-7 Cat. Operator skill and judgment have considerable bearing on the quality of the clearing job and the safety of the operation.

Figure 1.--Pioneer road built to facilitate clearing steep terrain. Note soil mixed with slash.

Slash disposal poses another problem that often has no simple answer. Piled slash produces a potential fire hazard, a disease problem, and an eyesore. Slash burning may present other difficulties; a complete burn might not be achieved, adjacent timber might be scorched; the fire might spread to surrounding areas and smoke contributes to air pollution. For the China Glenn job, slash piled at the toes of fills and below culverts provided excellent debris basins (fig. 3). It would seem a waste to burn (in accordance with Section 2.34 of the specifications) or otherwise dispose of these sediment traps, when one considers the impact sedimentation has had on the South Fork. The consequences of each option should be carefully weighed by qualified land management teams and new ideas sought; i.e., treating the piled slash to prevent fire or spread of disease, and educating the public as to why esthetically displeasing actions must be taken to prevent sedimentation.

Figure 2.--Slash and organic debris mixed with excavated material.

Figure 3.--Two examples of sediment trapped by windrowed slash.

Excavation and Compaction

Soil samples were taken from the selected route before construction and tested to determine moisture-density relationships, gradation, and consistency. Tests and experience led designers to decide that the weight of earthmoving equipment and other traffic would provide satisfactory compaction. Satisfactory compaction probably could be achieved in areas traversed by tracks of the earthmoving equipment if layer placing is employed, but tracks on the China Glenn Road generally were limited to two strips along the road prism. Lateral movement was restricted; the blade on the D-8 Cat used for moving earth was more than 14 ft. wide. This equipment left almost no compaction on the outside shoulders of fills where compaction is most needed (figs. 4 and 5).

Such fills were often left to stand at the angle of repose (70-80 percent) instead of the angle (67 percent) specified by the design. These conditions could have contributed to sloughing and settlement cracks parallel to the fill shoulders and to erosion due to the Labor Day storm (not surprising when one considers the minimum amount of compactive effort and the range in moisture contents). Laboratory tests showed that

Figure 4.--Wide tractor blade drifts fills and leaves windrowed shoulders with little compaction.

the optimum moisture content for compaction was 9.7 to 11.5 percent, but moisture contents measured in the fills ranged from 2.0 to 18.7 percent (figs. 6 and 7). Following the storm, areas on the cuts and fills evidenced the flow of soil, an indication that liquefaction had contributed to the erosion that occurred (fig. 8). The material on the surface of the cuts and fills was loose, probably in the range of 80 to 90 pounds per cubic foot (the loose unit weight according to the China Glenn Road Soils Report). Previous work done by Gardner and others[2] on similar type decomposed granitic soils in the Zena Creek area indicates that unit weights in this range would correspond to void ratios above the critical void ratio for these soils. Thus, the flow phenomenon was to have been expected under wet conditions.

[2]R. B. Gardner, M. J. Gonsior, and G. L. Martin. Zena Creek Road and Logging System Investigation. Unpubl. rep. on file, Intermt. For. & Range Exp. Stn., For. Sci. Lab., Bozeman, Mont. 1969.

Figure 5.--Material is left in a loose, unstable condition when fills are sidecast.

Figure 6.--Dust from compactor indicates very dry soils.

Figure 7.--Soils at stream crossings were saturated.

Figure 8.--Soil flows are apparent on this cut slope.

Figure 9.--Horizontal layer compaction is not being obtained in this fill.

When culverts were out of supply, fills were constructed by dozing material until the edge of the fill embankment was adjacent to the bedding area for the culverts. This appears to be a poor practice because horizontal layer compaction was not achieved in some of the higher fills and in other critical areas (fig. 9). On steep side slopes, horizontal layer placement and compaction required by the roadway excavation specifications cannot be achieved by using existing equipment. Figure 10 illustrates the point and demonstrates the need for new equipment and techniques.

Scrapers along with watering and rolling equipment could have produced a better embankment structure and, in cases of long balance points, probably would have been more economical. Some type of compaction on fill surfaces and other stabilization measures should be incorporated to hold fill material in place (fig. 11).

Figure 10.--Existing equipment makes horizontal layer placement difficult or impossible on steep side slopes.

Figure 11.--Stabilization measures are needed to hold fill material in place.

Consideration should be given to the treatment of cut slopes. Although cuts are made in steps, or terraces, they are often smooth, or nearly so because loose material sloughs down and fills the recesses. Some designers believe that these steps provide suitable catchments and retainers for loose soils and so improve chances for revegetation. However, the authors believe that loose materials and supporting steps will soon be deposited on the road because of the rapid disintegration that follows exposure as well as the erosive effects of wind, water, and frost. Continued observation of the cuts on this road will settle this difference in opinion.

It is tentatively recommended that a grader complete with slope blade be used to remove loose materials, smooth slopes, and incorporate into the road surface the materials removed. Subsequent treatments to retard rapid disintegration and raveling would be desirable, but treatments now known are extremely expensive.

Culverts

Several points of interest arose concerning culverts and their installation during the construction of the China Glenn Road. Dimpled connecting bands (fig. 12) were used on the 15-inch helically corrugated pipe that comprised most culvert footage. This type of band is a poor seal against leakage and allows a sizable change in alinement that can promote further leakage. The dimpled band is weaker than the standard band, particularly in tension. This weakness could be a problem because a large settlement at the outside shoulder of a fill would have a tendency to pull the culvert joints apart. Another factor that could contribute to tension on the bands and also to scour is placement of culverts on steep slopes. On this job, culvert slopes of up to 40 percent (fig. 13) could have been avoided by skewing culverts or using downspouts instead of installing culverts on slope and perpendicular to the road center line.

The flat-bottomed inlet ditch is of questionable value where small drainage areas are involved (fig. 14). The ditch will provide a sediment catchment at the culvert inlet, but it also opens up more of the hillside, which in turn causes more rapid erosion.

Figure 12.--Dimpled connecting band.

Figure 13.--Steepness of culverts could be reduced by skewing or using downspouts.

Figure 14.--Flat-bottomed inlet ditch opens up more of the hillside.

The bedding of culverts was generally good but, in a few cases beds were too deeply excavated, then backfilled to raise grade. It was observed on one of the small culverts that approximately the upper 8 feet of the culvert was not properly bedded before backfilling (fig. 15). The intent was to put camber into the culvert to allow for settlement; however, it is doubtful that 2 or 3 feet of fill would be heavy enough to hold the culvert in place. The authors believe that this practice could lead to pumping, piping, or to a flow path beneath the culvert. Camber should be accomplished by making a slight change in angle at the joints, not by bending the pipe. It is also recommended that camber be built in where settlements are largest, on the lower half of the culvert. Use of crawler tractors to excavate culvert beds disturbed natural stream channels above and below culvert installations. Use of a backhoe would allow excavation for proper bedding and avoid disturbing natural stream channels above and below culverts.

At the beginning of the project, the backfilled material around the culverts was compacted by the workers' feet or by tamping with tree limbs. Later, a gasoline engine-powered tamper was brought on the project and a much better compacting job resulted. (The requirement in the specifications pertaining to this equipment should be reviewed and made more specific.)

At least one culvert location had saturated soil that would have made poor backfill material. Fortunately, the inspector and the contractor agreed that the saturated material was to be mixed with drier soil (fig. 16) before being used for backfilling culverts. The specifications should be more specific concerning this important aspect of culvert installation.

The 36- and 48-inch-diameter culverts required in the larger fills and major drainages were given special attention by the contractor. These culverts were bedded well and were backfilled and hand compacted with utmost care.

Figure 15.--The upper end of this culvert is not bedded properly.

Figure 16.--Saturated soils are replaced with drier soils for bedding and backfilling at this culvert installation site.

Logging

Logging operations can contribute a sizable portion of the sediment received by streams in the logging area. During the China Glenn project, skidding tractors removed the soil's protective cover on steep grades. As a result, skid trails were eroded during the Labor Day weekend storm (figs. 17 and 18).

Generally, the best way to reduce sedimentation caused by roadbuilding is to finish the road and take stabilization measures as rapidly as possible. However, this method is virtually impossible when a new road is being used for a logging operation because of the damage done during tractor and jammer skidding. Cuts and fills are continually disturbed and the material on the road surface considerably displaced and reworked (fig. 19); therefore, final finishing and grading must be delayed until logging is finished.

Delay in finishing a road can lead to serious sedimentation problems since the drainage system will not function as designed. The China Glenn Road was designed as an outsloped road in order to move water from the road prism as quickly as possible. This road could not function as an outsloped road because longitudinal trenches were formed in the road surface by skidding tractors and the butts of skidded logs (fig. 20). To further complicate matters, a berm had been left along the outside shoulder of the road by the grading tractor and had not been removed by the grader on portions of the road. As a consequence, water concentrated on the road surface and ran down the road for considerable distances to spill off the fills at some low point. The berms probably were the single most important factor contributing to the erosion that occurred during the Labor Day storm.

Figure 17.--Steep skid trails increase the erosion hazard.

Figure 18.--Erosion and sedimentation produced by skid trail.

Figure 19.--Portions of road have been obliterated during logging operations.

Figure 20.--Damage to fill was caused by water that ran down the road and over a low point in the fill.

This drainage problem apparently has no simple solution given present techniques and equipment. Construction of a minimum standard road over which logging equipment could operate to remove timber might be an interim solution. This would be a contour road with a rolling grade similar to the pioneer road on the China Glenn route. Earthwork would be kept to a minimum, but necessary drainage structures would be included to avoid the water concentration potential created by an unfinished higher standard road. At the same time, the proposed road would stay within the grading limits of a higher standard road. As soon as logging is completed on a section of road, construction could be completed to the standard required for either a haul road or a system road. Loggers probably would not like this approach, but the concept has merit as was evidenced by the complete lack of erosion on one-half mile of pioneer road after the Labor Day storm. Freedom from erosion on the pioneer road (in which no drainage structures had been installed) can be explained by several factors. Among these were minimum disturbance to the natural drainage patterns, flat grade or relatively short stretches of unbroken grade, and loose, absorbent soil conditions.

Alinement

The standard of a road is a management decision based on a variety of inputs: intended use, economy, safety, environmental impact, esthetics, topography, geology, watershed, etc. The main purpose of the China Glenn Road was to serve a timber sale. Management decided to construct an SL-12 outsloped road; the history of sedimentation associated with roads in the South Fork area dictated a minimum impact road. Management believed that this road standard would result in acceptable environmental impact. The road was designed as an SL-12 outsloped road and the plans were accepted by the land managers.

During field inspection, land managers expressed concern that the road would have more impact than had been anticipated. They felt that cuts and fills were larger than desirable or necessary (fig. 21). Apparently, they could not fully visualize the final product from the design sheets, which indicates a need for better communications. This

Figure 21.--Examples of large cuts, looking upstation (top) and downstation (bottom) from a point on the road.

misunderstanding demonstrates the kind of problem that can arise by trying to control a factor such as environmental impact by assigning a road standard. In this case, road alinement (vertical and horizontal), not the road standard, was the major reason for the size of cuts and fills.

Use of graphic aids during the design stage might improve communications between the land manager and engineer. Oblique aerial photographs on which the road has been superimposed or profiles that show maximum cut and fill heights might also be valuable.

The problem described above demonstrates the importance of flexibility in a contract, as well as in involved personnel. In this case, Forest Service personnel cooperated quickly and the remainder of the road was redesigned to alleviate the problem.

Figure 22.--Three examples of damage that occurred during the storm.

Storm Damage

The storm mentioned throughout this report served to point up problems that can result from road construction and logging in the Idaho Batholith. Culverts carried little or no water; so storm runoff due to overland flow was small. Water concentrations within the road prism and on logging skid trails did the damage (fig. 22).

A survey to determine road conditions was conducted after the storm. An estimated 165 cu.yd. of soil had been removed from fill slopes by erosion and slumping and deposited at or below the toes of fills. Most soil movement was localized and had resulted in long, narrow gullies and slide scars of less than 5 cu.yd. in volume; however, a few relatively large failures had occurred that ranged in size from 20 to 35 cu.yd. Fortunately, most of the soil was trapped in slash and other debris at the toes of fills. In some instances, soil traces were found as far as 300 ft. downslope from the toes of the fills, but soil reached a live stream in only one location. Significant soil movement from cut slopes and skid trails was also observed, but movement generally was halted by the road surface.

Below a depth of about 1 ft., soil in fills was at or near the placement moisture content, even though the storm lasted several days. The edges of fills underwent appreciable settlement, as was evidenced by frequent cracks and differential surface movements. Most of the volume changes probably occurred within 1 or 2 ft. of the surface because of the extremely loose condition of surface materials following construction and the relatively shallow penetration of moisture during the storm. If the fills become extensively saturated--as they might be during spring runoff--resulting soil movement could be significant. Proper road drainage along with settlement of fills should help to alleviate the erosion hazard.

SUMMARY AND CONCLUSIONS

During the summer and early autumn of 1970, a research team from the Forest Engineering Research project of the Intermountain Forest and Range Experiment Station observed the construction and performance of the China Glenn Road, Warren District, Payette National Forest, Idaho. This road was designed to serve a salvage timber sale and ultimately as a permanent part of the National Forest transportation system.

Payette Forest personnel operated as a team in an attempt to achieve minimum environmental impact. Route and design standards were selected on the basis of recommendations from soil scientists, hydrologists, engineers, and other professional experts. Moreover, careful inspection and control were exercised throughout the construction period. In short, all practical measures were taken to achieve a quality result in keeping with the Forest Service objective to minimize sedimentation problems in the Idaho Batholith.

Erosion problems encountered during the unexpected Labor Day weekend storm were largely attributed to incomplete shaping and grading. Except for these difficulties, the designers are reasonably satisfied that the China Glenn Road has been constructed and will perform as anticipated. That is, they feel that the China Glenn Road satisfies the objectives and criteria (environmental and otherwise) for which it was designed.

The authors are of the opinion that a gap remains between possible and achieved results. This is not to say the designers have not achieved their objectives, but to indicate that design criteria were more lenient than ideal.

In part, this gap can be attributed to the public's intolerance of short-term visual impacts. As a consequence, reasonable citizens and public land managers must distinguish between legitimate and frivolous grievances pertaining to logging and road construction.

The gap is partly attributable to the lack of improved equipment and techniques suited to adverse conditions encountered in areas such as the Idaho Batholith. Equipment and techniques needed include the following:

(1) Equipment that can properly and efficiently clear steep slopes;

(2) Equipment for excavation and fill placement on steep slopes; and

(3) Alternatives to conventional tractor skidding in moderately steep terrain.

Finally--and perhaps the most important part of the gap--is the fact that limitations on funds and time deprive designers and builders sufficient latitude to seek the ideal.

The authors conclude that when roads are to be used for logging activities other than hauling, efforts during final construction phases are wasted. Not only is the travel surface subjected to extreme reworking, but cut and fill slopes also are severely disturbed by skidding, decking, and other activities. Instead of attempting to achieve and maintain a stabilized final cross section, more attention should be given to controlling sediment-laden water that will pass over the road prism or through the culverts if precipitation occurs.

Methods must be radically improved to control water and its disposal from unprotected road prism surfaces. Slash and debris piles remaining below the toes of the fills constituted one of the best means of controlling sediment during the storm September 4-7, 1970. Unless fire, disease, or other hazards preclude such use of slash and debris, undesirable appearance would seem to be outweighed by effectiveness of these materials as sediment catchments.

The authors suspect that outsloping is more an idealistic concept than a realistic solution to the water control problem. In theory, water generally will be uniformly distributed in minimal concentration over the road shoulder. However, unless the road can be graded to close tolerances and left undistorted, concentration is virtually unavoidable. Depressions left by wheels allow water to concentrate and run along the road. Even if the road has no grade, water will tend to concentrate and spill over depressions. If soils are loose and erodible, slight concentrations tend to erode depressions and channels that lead to greater concentrations and accelerated erosion. Although it can be argued that such problems rarely occur, the major part of all stream sedimentation is caused by relatively infrequent circumstances. Most of any stream's annual sediment load is contributed and transmitted (under natural or disturbed conditions) during a few hours or days. It is tentatively recommended that outsloping be specified only where surfaces are relatively nonerodible (e.g., at full-bench sections).

Road "standard" is not necessarily synonymous with "alinement." Still, several Forest Service officers were surprised and disappointed by relatively high cuts and fills on the China Glenn Road; so misunderstandings evidently occurred during the planning and design stages as to the meanings of "standards," "minimum impact," etc. More input is needed from landscape architects, watershed analysts, soil scientists, geologists, and others during planning and design stages, and greater participation as staking and construction progress.

Finally, thought must be given to matters of perspective and time. To reach the new China Glenn Road, one travels over several miles of similar terrain on a road constructed several years ago. In addition, after passing the intersection of the two roads, one can drive several miles down this old road to the South Fork of the Salmon River. The old road traverses terrain that is often steeper and more hazardous than any along the route of the China Glenn Road, and many of its cut and fill slopes are significantly longer and higher than the highest on the new road. Yet, few fill slopes

can be found that are distinguishable from the undisturbed terrain; all are covered with native vegetation and none appear to be eroding. Although they are not completely stabilized, most cut slopes are supporting vegetation--often young fir, spruce, and pine trees. Except for occasional rocks that have fallen from the cut slopes and a few short stretches of small eroded gullies the travel surface is relatively smooth and stable.

This older road crosses several live streams. Examination of these streams upstream and downstream from the road crossings disclosed undistinguishable sedimentation conditions. In short, this older road has become almost a natural part of the topography. It is reasonable to assume that if some moderate maintenance practices are continued it will more closely approach "zero impact" each year. It is no less reasonable to assume that the same will be true of the China Glenn Road and probably in less time because of its more favorable location.

Nothing said here is intended to excuse carelessness or to rationalize increases, however temporary, in sediment delivery to streams. Conceivably, the initial impact of roadbuilding upon watersheds can be significantly reduced in the Idaho Batholith and elsewhere. The main purpose of these observations is to point out that natural processes eventually will establish a new and acceptable equilibrium and that ways can be found to hasten establishment of equilibrium. The challenge lies in minimizing initial environmental disturbances while seeking long-term stability and renewability. The greatest problem is the urgency for solutions because of the conflict between increasing consumption of resources and increasing opposition to environmental disruption.

Recommendations

Given the existing economic and technical framework, the following recommendations are proposed:

1. The primary objective should be to minimize initial environmental impact; therefore heights of cuts and fills and widths of travel surfaces must be minimal. The main criterion for alinement should be the minimum negotiable radius of curvature. Losses in speed, sight distance, and steering error tolerances must be accepted and compensated for by restricting and scheduling traffic and by providing turnouts only where terrain is favorable. Also, turnarounds might be reduced by using loading equipment for turning logging trucks and other vehicles. Signs should be provided to inform drivers unfamiliar with the locations of and the distances between turnouts. Greater use could be made of radio equipment to promote safe and efficient transportation during periods of logging or other heavy use.

2. No sediment from the cut slopes or the travel surface should be allowed to leave the travel surface unless the spillage is specifically intended and controlled. Unless cut slope and ditch stabilization are included, insloping does not usually provide a satisfactory solution. The toe of a cut slope is often a source of sediment; the travel surface affords greater opportunity for safely channelling waterflows. Grading and surface treatments should be incorporated into the design to accommodate water and accompanying erosive tendencies. Unless sedimentation can be prevented, water should not be allowed to leave the travel surface without being passed through filtering or settling facilities, or discharged far enough away from perennial or ephemeral streams to assure infiltration and clarification before reaching said watercourses.

It is recommended that roads be designed to serve the dual purpose of accommodating vehicles and transporting and distributing water. Designs should include special provisions to prevent or control sedimentation.

3. Sediment catchments should be provided at the toes of all fill slopes. Unless unacceptable from an esthetic point of view, the slash and debris that result from clear-

ing should remain piled just below the toes of the fills. Heights of catchment barriers should be sufficient to trap all material likely to be eroded from the fill slopes.

4. Efforts should be continued to find ways of accelerating revegetation of cut and fill slopes after roadbuilding and logging. Native vegetation would be preferable, but not necessary, if exotic and other introduced species do not create long-term problems.

When and if significant technological advances are made in the development of construction equipment, in logging, and in artificial erosion control, additional recommendations may be possible. For now, those presented above appear to be the only practical measures that can be taken.

Future Study

Periodic inspections of the China Glenn Road will be made to photograph and record its performance. Personnel might be on the site during spring snowmelt to observe and document modes of erosion and experimental control measures. One recently discovered chemical erosion-control treatment will be used on cut, fill, and travel surfaces, and other mechanical and chemical treatments will also be tested. In addition, one large fill has been equipped with metal reference standards designed to enable determination of surface erosion losses as well as total settlement. Intermittent measurements at this fill will be continued.

Extension of the road is planned for the 1971 field season, and its construction and performance will be observed.

The structural behavior of cut slopes remains a mystery; so studies will be continued to find more accurate methods of assessing stability.

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- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)
- Reno, Nevada (in cooperation with University of Nevada)